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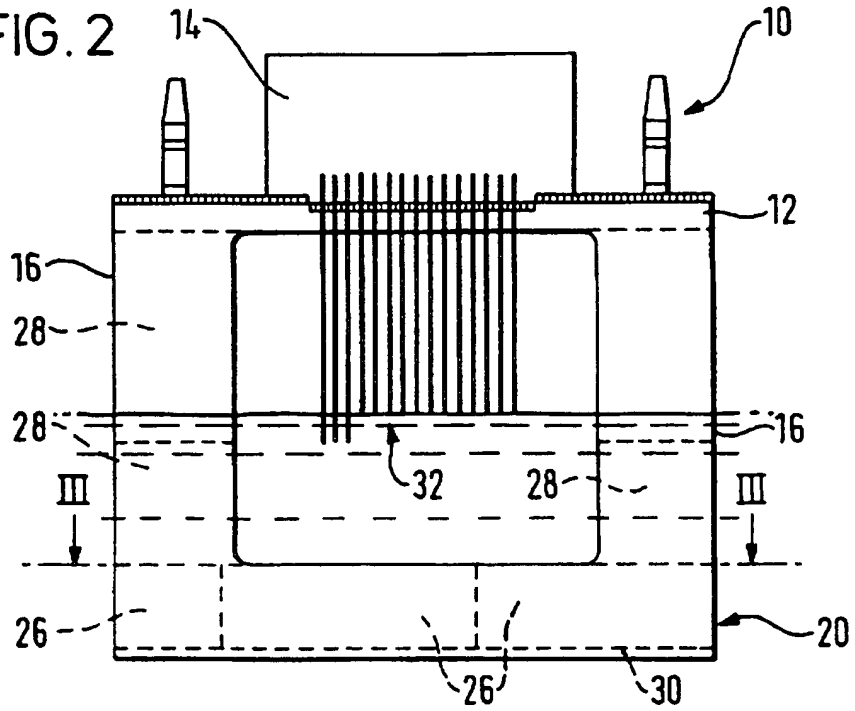
(54) Storage of Liquid Hydrocarbons

(57) A semi-submersible vessel 10 comprises a superstructure 12, a plurality of legs 16 extending from the superstructure and a pontoon 20 rigidly connecting respective end portions of the legs disposed remote from the superstructure to form a buoyant structure. The pontoon 20 is adapted to define storage tanks for produced liquid hydrocarbons, ballast tanks 26 for receiving sea-water ballast and a ballast zone 30 for housing semi-permanent or permanent ballast having a greater density than sea water.

FIG. 2



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

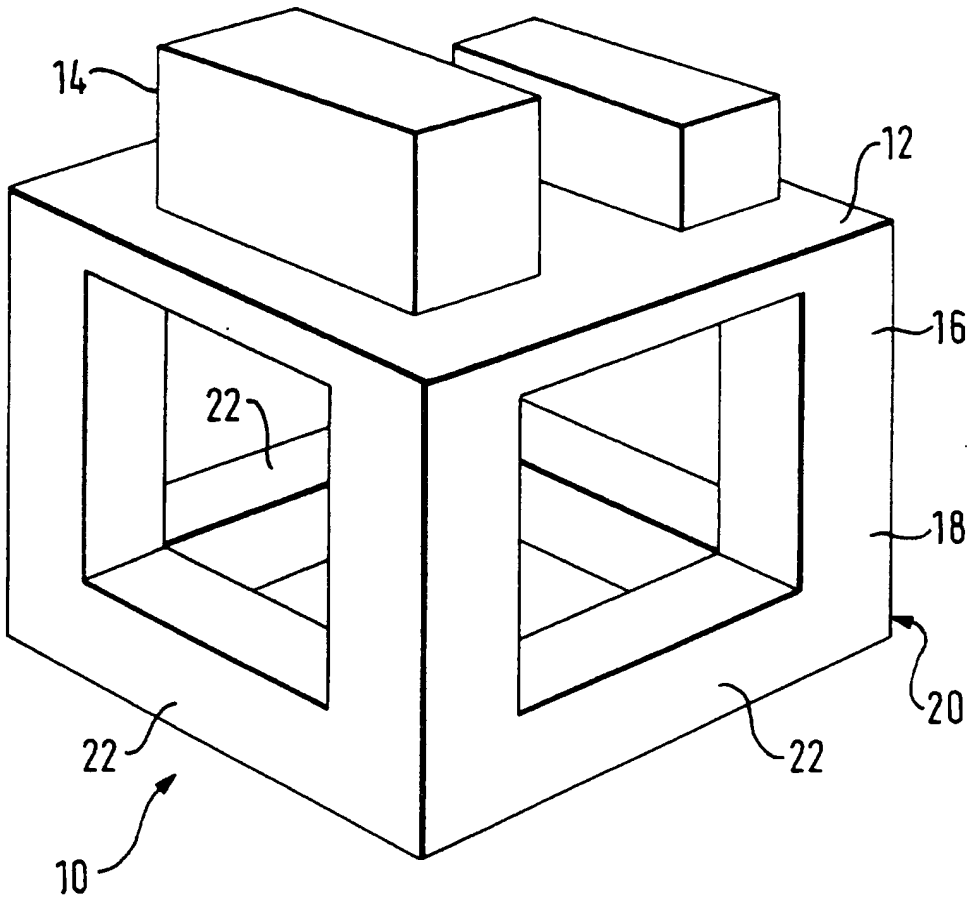
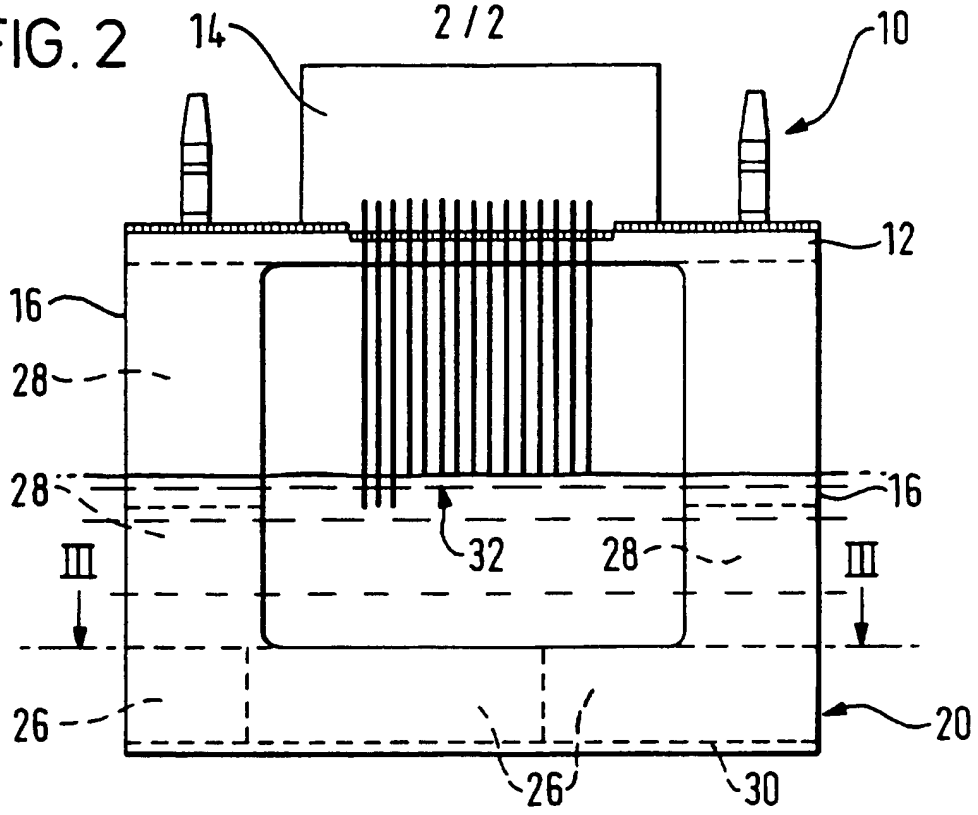


FIG. 1

FIG. 2


14
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III
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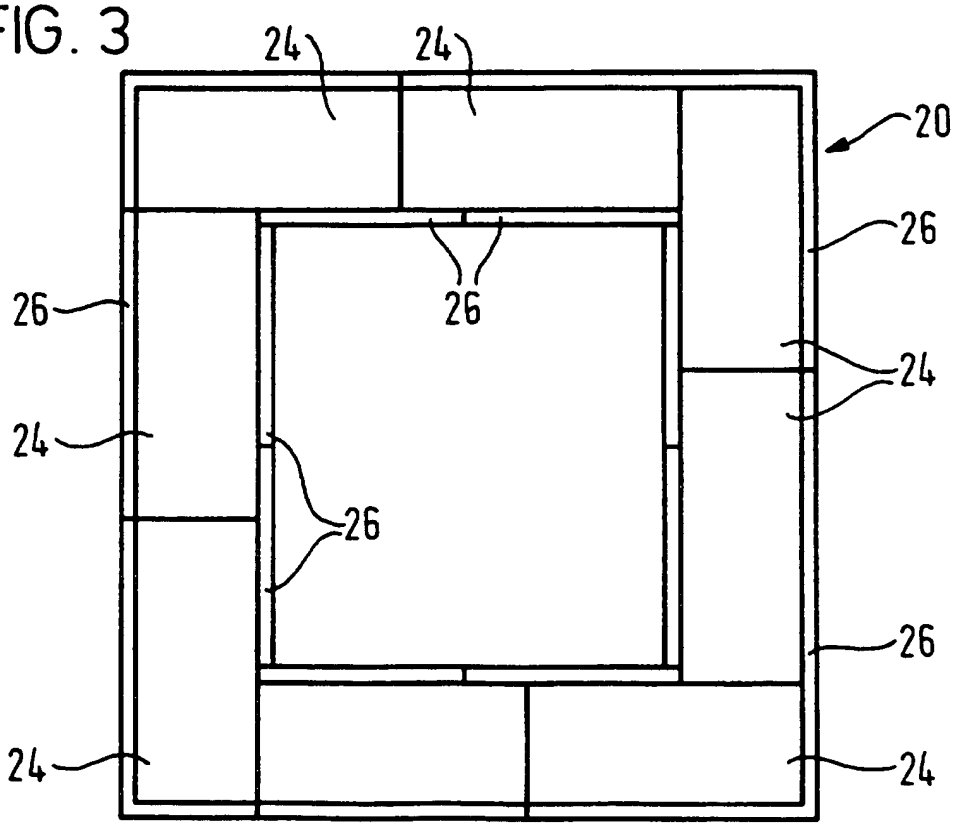
FIG. 3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Storage of Liquid Hydrocarbons

The inventi n relates to floating liquid hydrocarbon production systems and particularly to the storage of the liquid hydrocarbons.

UK patent application no. 9422852.5 (filed November 12th, 1994) discloses a semi-submersible vessel which comprises a storage tank for storing produced liquid hydrocarbons, the storage tank being arranged such that, in use, it is submerged below the surface of the sea.

Liquid hydrocarbons are introduced into the storage tank by an 'oil over water' displacement technique whereby the liquid hydrocarbons introduced into the tank cause progressive downward displacement of sea water already in the tank until the tank is substantially full of the liquid hydrocarbons. As the liquid hydrocarbons are pumped out of the tank, for example to a tanker, sea water is caused, or allowed, to enter the tank to replace the liquid hydrocarbons. Accordingly, the tank is always filled with liquid: ie. with (i) sea water alone; (ii) liquid hydrocarbons alone; or (iii) a mixture of liquid hydrocarbons and sea water in two separate layers. Since the density of sea water and liquid hydrocarbons is similar (sea water has a specific gravity of 1.025 and liquid hydrocarbons typically have a specific gravity of

0.85), an advantage of this technique is that the change in draft of the vessel is minimised as the storage tank is filled and emptied.

A problem with the 'oil over water' displacement technique is that a certain amount of contamination of the sea water occurs unless the two fluid media are separated by physical means. It will be understood that the pressure on the operators of such vessels not to pollute the seas in which they operate has increased considerably in recent years and so it is desirable to prevent contamination of the sea water used to ballast the vessel.

In the above-mentioned patent application, it is proposed that a membrane can be located between the sea water and stored liquid hydrocarbons. However, this solution is only satisfactory if the sides of the storage tank are relatively smooth and even then some seepage past the membrane can occur. It will be understood that in most cases, the structure of such vessels is such that the internal surfaces of the storage tank will not be smooth. In order to make the structure suitably strong, the internal surface of the tank will have many stiffening members attached thereto rendering such a membrane ineffective for practical purposes.

It is an object of the invention to at least

partially overcome the above described problem.

Accordingly the invention provides a semi-submersible vessel comprising a superstructure, a plurality of legs extending from said superstructure and means rigidly connecting respective end portions of said legs remote from said superstructure to form a buoyant structure, said connecting means being adapted to define a storage tank means for produced liquid hydrocarbons, ballast tank means for receiving sea-water ballast and a ballast zone for housing semi-permanent or permanent ballast having a greater density than sea water.

Preferably said storage tank means is disposed between opposed said ballast tank means.

Preferably, in use, said ballast zone at least partially defines a base portion of said vessel.

Advantageously, in use, said ballast zone extends below said storage tank means and/or said ballast tank means.

Preferably, said ballast zone contains drilling mud.

The invention also includes apparatus for storing liquid hydrocarbons in underwater locations, said apparatus comprising means defining at least one storage tank for such liquid hydrocarbons, at least one tank for receiving sea-water ballast, means for

filling and emptying the or each said ballast tank, means for filling and emptying the or each storage tank, and means for housing a semi-permanent or permanent ballast having a greater density than sea water.

Preferably, the housing means contains a said semi-permanent ballast comprising drilling mud.

The invention also includes a method of ballasting a semi-submersible vessel for storing liquid hydrocarbons in an underwater location, the method comprising the step of providing said vessel with a semi-permanent or permanent ballast having a density greater than sea water.

Preferably, the method comprises the step of providing said vessel with a semi-permanent ballast comprising a drilling mud.

The invention also includes a method of operating a semi-submersible vessel for storing liquid hydrocarbons, comprising adjusting the amounts of sea water and liquid hydrocarbons in respective tank means therefor such that addition or removal of liquid hydrocarbons does not substantially alter the buoyancy of said vessel and providing said vessel with a quantity of ballast which is denser than sea water which quantity is unaltered during such addition or removal.

Preferably, said ballast comprises a drilling mud.

The invention also includes a method of storing used drilling mud comprising housing said mud in at least one ballast tank of a semi-submersible vessel.

In order that the invention may be well understood, an embodiment thereof, which is given by way of example only, will now be described with reference to the drawings, in which:

Figure 1 is a schematic perspective view of a semi-submersible vessel;

Figure 2 is a detailed side view of the vessel looking from the left in Figure 1; and

Figure 3 is a plan view of the vessel on the plane of line III-III in Figure 2.

Referring to the Figures, a semi-submersible vessel 10 comprises a superstructure 12 which includes a utilities and processing module 14. Four legs 16, one at each corner of the vessel, extend from the superstructure and are rigidly connected at respective end portions 18 thereof by a connecting means 20, hereinafter referred to as a pontoon. The legs 16 preferably have a rectangular cross-section.

The pontoon 20 comprises tubular portions 22 extending between the legs 16. These portions 22 preferably have a rectangular cross-section.

As shown in Figure 3, the pontoon 20 d fines storage tank means comprising a plurality of storage tanks 24 for storing produced liquid hydrocarbons and ballast tank means comprising a plurality of tanks 26 for receiving sea-water ballast. The sea water ballast tanks 26 are arranged such that there is one such tank or tanks on either side of each storage tank 24.

Additional sea water ballast tanks 28 are provided in the legs 16.

Means (not shown) are provided for pumping produced liquid hydrocarbons to and from the storage tanks 24 via the legs 16. Additionally means (not shown) are provided for filling and emptying the sea water ballast tanks 26 and 28 so that the draft of the vessel 10 can be maintained substantially constant as the storage tanks are loaded and unloaded. Such means will be familiar to those skilled in the art and accordingly are not described in any detail herein.

The pontoon 20 also defines a ballast zone 30 for receiving a semi-permanent or permanent ballast of greater density than sea water. In the present specification, semi-permanent ballast is to be taken to mean a ballast, the amount of which is not adjusted during normal usage of the vessel. That is the quantity of the ballast remains unaltered.

Th zone 30 is disposed at the lowermost position of the vessel 10 and extends beneath the storage tanks 24 and sea water ballast tanks 26. It will be appreciated that in the embodiment the ballast zone forms a base portion of the vessel.

In use, the ballast zone 30 preferably contains a semi-permanent ballast in the form of used drilling mud. Drilling mud is typically a mixture of clays, water, density increasing agents such as barite and sometimes thixotropic agents such as bentonite which is pumped down through a drilling pipe to cool, lubricate and flush debris from the drilling assembly. Typically used drilling mud has a specific gravity of 3.5.

In operating the vessel 10, liquid hydrocarbons are pumped from undersea wellheads to the process and utilities module 14 via a plurality of pipes 32 known as risers. The liquid hydrocarbons are passed from the process and utilities module to the storage tanks 24 via the legs 16. As liquid hydrocarbons are pumped into the tanks 24 sea water is removed from the ballast tanks 26 and 28 as required so that the buoyancy of the vessel remains substantially unaltered, ie the draft of the vessel remains substantially constant. When the stored liquid hydrocarbons are removed from the tanks 24, for

example by pumping into a tanker, sea water is caused to enter the ballast tanks 26 and 28 for the same purpose.

During the loading an unloading process the quantity of ballast in the ballast zone 30 remains unaltered.

It will be appreciated that it is undesirable to have empty storage tanks for liquid hydrocarbons located in the pontoon since this adversely affects the stability of the vessel. It would be possible to compensate for the presence of the empty storage tanks by providing sufficient sea water capacity in the pontoon. However, when compared with a pontoon in which the tanks are permanent filled with liquid hydrocarbons and/or sea water this would require a large increase in the volume of the pontoon which would add significantly to the manufacturing costs. By providing a zone for a semi-permanent or permanent ballast of greater density of sea water it is possible to avoid this problem. Additionally, by providing some sea water ballast tanks in the legs, the volume of the pontoon can be minimised for a given liquid hydrocarbons storage capacity.

The ballast in the ballast zone could be a mixture of pig iron and cement having a specific gravity in the region of 4.5 or a cement which would

have a specific gravity of about 2.5. It will be appreciated that a disadvantage of using these ballasting materials is that they will be relatively expensive. By utilising used drilling mud three advantages can be obtained: firstly, the used drilling mud has no commercial value and therefore the overall cost of the vessel can be reduced; secondly, the mud can be pumped into and out of the ballast zone. This provides the advantage that the ballast zone can be emptied of ballast for inspection and damage repair (it will be appreciated that inspection of the ballast zone may be periodically required by insurers or certification authorities and that removing cement ballast from the ballast zone would involve considerable expense and wastage); and thirdly, disposal of used drilling mud which is a pollutant is a problem for oil companies and therefore it is highly beneficial to provide a relatively long term use for this material by housing it in a ballast zone of a semi-submersible vessel.

It will be appreciated that a further advantage of the arrangement of ballast tanks in the embodiment is that the storage tanks 24 are protected on two sides reducing the danger of damage thereto which might lead to spillage of the stored liquid hydrocarbons.

CLAIMS:

1. A semi-submersible vessel comprising a superstructure, a plurality of legs extending from said superstructure and means rigidly connecting respective end portions of said legs remote from said superstructure to form a buoyant structure, said connecting means being adapted to define a storage tank means for produced liquid hydrocarbons, ballast tank means for receiving sea-water ballast and a ballast zone for housing semi-permanent or permanent ballast having a greater density than sea water.

2. A vessel as claimed in claim 1, wherein said storage tank means is disposed between opposed said ballast tank means.

3. A vessel as claimed in claim 1 or 2, wherein, in use, said ballast zone at least partially defines a base portion of said vessel.

4. A vessel as claimed in any one of claims 1 to 4, wherein, in use, said ballast zone extends below said storage tank means and/or said ballast tank means.

5. A vessel as claimed in any one of the preceding

claims, wher in said ballast zone contains drilling mud.

6. Apparatus for storing liquid hydrocarbons in underwater locations, said apparatus comprising means defining at least one storage tank for such liquid hydrocarbons, at least one tank for receiving sea-water ballast, means for filling and emptying the or each said ballast tank, means for filling and emptying the or each storage tank, and means for housing a semi-permanent or permanent ballast having a greater density than sea water.

7. Apparatus as claimed in claim 5, wherein said housing means contains said semi-permanent or permanent ballast.

8. Apparatus as claimed in claim 7, wherein said housing means contains a said semi-permanent ballast comprising drilling mud.

9. A method of ballasting a semi-submersible vessel for storing liquid hydrocarbons in an underwater location, the method comprising the step of providing said vessel with a semi-permanent or permanent ballast having a density greater than sea water.

10. A method as claimed in claim 9, comprising providing said vessel with a semi-permanent ballast comprising a drilling mud.

11. A method of operating a semi-submersible vessel for storing liquid hydrocarbons, comprising adjusting the amounts of sea water and liquid hydrocarbons in respective tank means therefor such that addition or removal of liquid hydrocarbons does not substantially alter the buoyancy of said vessel and providing said vessel with a quantity of ballast which is denser than sea water which quantity is unaltered during such addition or removal.

12. A method as claimed in claim 11, wherein said ballast comprises a drilling mud.

13. A method of storing used drilling mud comprising housing said mud in at least one ballast tank of a semi-submersible vessel.

14. A method of ballasting a semi-submersible vessel substantially as hereinbefore described with reference to the drawings.

15. Apparatus for storing liquid hydrocarbons in

underwater locations substantially as hereinbefore described with referenc to the drawings.

Patents Act 1977 **Examiner's report to the C mptroller under Section 17** **(The Search report)**	Application number GB 9520736.1
Relevant Technical Fields (i) UK Cl (Ed.N) B7A (AAAQ, ACA, A430A); E1H (HB) (ii) Int Cl (Ed.6) B63B 25/00, 25/08, 25/10, 25/12, 25/14, 25/16, 35/44 E02B 17/00; E02D 29/00	Search Examiner A HABBIJAM Date of completion of Search 23 NOVEMBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Documents considered relevant following a search in respect of Claims :- 1-5, 11, 12, 15

Categories of documents

X:	Document indicating lack of novelty or of inventive step.	P:	Document published on or after the declared priority date but before the filing date of the present application.
Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	E:	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	&:	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2121733 A	(GOTAVERKEN ARENDAL) see ballast and oil tanks 23, 24 and further tanks 25 (ballast zone): Figure 2 in particular	1, 3
A	US 3837310	(TOYAMA) see oil storage tank 1, sea-water ballast tank 2 and further balast means 16, 17	common matter of Claims 1, 6 and 11

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).